Improving instructional video design: A systematic review

Matthew Fyfield, Michael Henderson, Michael Phillips
Monash University, Australia

Instructional videos are increasingly part of the teaching practices of educators across all sectors. The most common theoretical lens used to design and evaluate instructional videos has been to apply principles emerging from the cognitive theory of multimedia learning. However, these principles have been largely developed from research using instructional media other than videos. In addition, there is no comprehensive list of principles that have been shown to improve learning from instructional videos. Therefore, this paper seeks to identify principles of video design that are empirically supported in the literature. A systematic literature review was conducted, with a final analysis of 113 papers describing 28 principles. While some of the existing cognitive theory of multimedia learning principles, notably *coherence*, *segmenting* and *learner control*, have been found to improve learning from instructional videos in a variety of contexts, others, such as *redundancy* and *modality*, are not supported. These findings serve as clear guidance to instructional designers creating educational video content. In addition to describing the breadth of research in the field, this paper also found that the development of the research field suffers from a lack of coherence and is in urgent need of clear nomenclature and improved reporting of media and research design.

Implications for practice or policy:

- Instructional videos that are shorter, segmented, coherent and paired with learning activities are more likely to lead to improved learning gains in students.
- Researchers reporting on the use of videos should provide comprehensive descriptions of media, including links to the media where possible.
- Designers of instructional videos should critically evaluate design principles established for non-video media.

Keywords: instructional video, systematic review, cognitive theory of multimedia learning, video length, educational video principles

Introduction

The use of video in education has a long history, but the advent of online streaming and mobile learning in recent years has made watching instructional videos an almost ubiquitous part of formal learning. In addition, with the rise of YouTube and other media sharing sites, it has become easier to not only watch but also create and share videos by and for a wider range of educators. A growing body of literature covering K-12, tertiary, adult, and professional education affirms that instructional video is not only popular with students (Henderson et al., 2017; Murray et al., 2015) but can also enhance student learning (Castro-Alonso et al., 2019; Höffler & Leutner, 2007). However, videos are not a panacea for improving educational outcomes. Research has shown that suboptimal use of educational videos can simply be a waste of time (Hobbs, 2006) and even lead to inaccurately inflated perceptions of understanding in students (Szpunar et al., 2014).

The most common theoretical lens used to design and evaluate instructional videos has been to apply principles emerging from the cognitive theory of multimedia learning (CTML; Mayer & Moreno, 1998). CTML proposes that certain multimedia design principles lead to improved learning outcomes due to the nature of human cognitive architecture. In his seminal chapter explaining the role of CTML, Mayer (2014) presented a representative list of 15 principles for efficient multimedia design. These design principles are often uncritically applied to the production of instructional videos (e.g., Brame, 2016) but have largely been established using instructional materials other than videos, which is a conclusion that is further evidenced by this literature review. In order to guide not only future research but also the costly process of instructional video development (Hollands & Tirthali, 2015), it is important to determine whether instructional design principles shown to be effective for other multimedia apply to instructional videos. The need for this work was highlighted by Mayer et al. (2020), who noted a number of boundary conditions which hampered the replication of previously established principles, such as *modality*. However, to date, there has not been a systematic review of research findings from studies on instructional design using only videos as the instructional media.

This systematic literature review seeks to identify the principles of video design that are empirically supported in the literature. Due to the nature of the research literature, as discussed later in the paper, this systematic literature review is not limited to research using experimental design but also includes studies reporting on empirical data derived from quasi-experimental and case study methods, along with analyses of existing data such as that harvested from massive open online course (MOOC) interactions. Accordingly, this review does not set out to establish the comparative strength of the various principles, but instead to better understand the breadth and nature of research in this field. While differing approaches limit comparison and preclude the generation of effect sizes, the papers ranging from experimental to naturalistic settings provide a rich overview of the state of research into the design of instructional videos in order to guide future research and the practice of educators.

Instructional video

This research is focused on investigating research into the design of instructional videos. Instructional video is a "meta-genre" (Winslett, 2014, p. 489) that encompasses at least 19 discreet design types (Fyfield, 2020). While the term *video* may seem self-explanatory, defining an instructional video is more difficult than it may seem. For instance, a distinction has, at times, been made in the literature between *video*, which "captures images of the outside world" and *animation*, which is a constructed series of images designed to "trigger the perception of continuous change" (Lowe & Schnotz, 2014, p. 515). However, some authors (e.g., Boucheix & Forestier, 2017; Castro-Alonso et al., 2015) termed the instructional materials in their studies *animations* even when they were actually live captured video. Conversely, other authors, such as Schüler et al. (2013), termed their media *animations* when they were static line drawings.

In this paper, we adopted the definition of video as "a format of presenting information as a stream of dynamic visual and auditory content" (Ibrahim et al., 2012, p. 220), which includes live shot action, dynamic cartoons, stop-motion and computer-generated animations. We adopted this definition because it is broad enough to capture the wide range of descriptions of video presented in the literature while also discrete enough to exclude other forms of multimedia.

More specifically, instructional videos are those with an explicit learning goal or an intent to teach factual, conceptual, or procedural knowledge (ten Hove & van der Meij, 2015). Examples can include short explainers or full-length lectures; outline procedural or skills-based knowledge, such as how to use a piece of equipment, how to write a paragraph, or how to search a database; or prompt conceptual change including the correction or introduction of broad concepts (Muller, Bewes et al., 2008). These kinds of instructional videos have content, concepts and skills that are explicitly explained (Winslett, 2014) and therefore differ from other narrative and entertainment video media such as those commonly found in television and film.

According to Mayer's conceptualisation of CTML, multimedia learning is defined simply as a "learner's construction of knowledge from words and pictures" (Mayer, 2014, p. 3). As a consequence of this broad definition, CTML principles have been applied to all forms of multimedia. However, we argue that instructional video is a distinct form of multimedia. Not only have instructional videos been shown to lead to higher learning gains than static images such as diagrams (Armstrong et al., 2011; Castro-Alonso et al., 2015; Höffler & Leutner, 2007; Wang & Tseng, 2019) but it also has unique features and challenges that demand a careful selection and application of learning principles. For example, a key difference is that content in a video is delivered in a continuous dynamic stream (Ibrahim et al., 2012) forcing learners to process information at a determined pace. When this information progresses too fast for a particular learner, this can lead to cognitive overload, negatively affecting learning gains – a result known as the transient information effect (Leahy & Sweller, 2016). This effect has been shown to be more likely in instructional videos than other multimedia (Hatsidimitris & Kalyuga, 2013) and is such a moderator of student learning that Clark and Mayer (2016) offered cautionary advice against the use of videos, advocating instead that "a series of static frames should be your default graphic" (p. 84). Despite some of the challenges associated with the use of instructional videos, the volume and frequency of use of instructional videos in a wide variety of educational contexts warrants further investigation.

Previous reviews of the use of instructional videos in education

This section outlines five prior reviews of the literature concerning the ways in which videos have been used in education and the types of videos used. These are differentiated from the reviews in the next section as they deal with pedagogies and popular instructional media, rather than experimental studies into instructional video design.

In a systematic review, Kay (2012) provided a broad overview of the history of instructional videos, which the author called *video podcasts.* Kay identified benefits and challenges of instructional videos but also several concerns regarding the way in which the literature reported the methods and data. These concerns included insufficient description of the media, limited sample scope and reliability issues. The same concerns once again emerged in the current review and are discussed later. In a similar systematic review, Winslett (2014) analysed 703 studies of videos used in higher education, with the goal of "identifying and describing the outcomes videos are being used to address and the production styles currently at play" (Winslett, 2014, p. 489). Both Kay (2012) and Winslett (2014) confirm that instructional video use was prevalent in education settings; however, neither of these reviews identify the design principles used in educational videos – which is the focus of the current review.

There have also been three notable non-systematic reviews that used CTML as a lens to evaluate the designs of existing instructional videos (see Brame, 2016; Lucas & Abd Rahim, 2017; C. Yue, Kim et al., 2013). These reviews accepted the principles of multimedia design uncritically, assuming that principles established in experiments using a range of learning media would apply equally to videos. However, more recent findings (see H. Lee & Mayer, 2018) suggested that some principles of design that have been found to improve learning in static media may not have the same effect when applied to instructional videos. Therefore, this review aimed to isolate studies that have used videos as the instructional media in order to establish which design principles the literature supports applying to this specific media type.

Systematic reviews into learning from instructional videos

In contrast to the reviews in the last section that dealt with existing instructional videos and their use, the three systematic reviews in this section reviewed the findings of studies drawing on experimental designs. They are, therefore, focused on establishing or evaluating principles for instructional video design. In their systematic meta-analysis, Höffler and Leutner (2007) found an overall advantage of learning from dynamic rather than static pictures, with an effect size of $d = 0.37$. The authors also made a major contribution to the development and evaluation of design principles for instructional video, as they reported effect sizes on design principles such as redundancy, animation type, level of realism, type of knowledge required, signalling and instructional domain. However, the 12 years that have passed since Höffler and Leutner's review have produced a vast increase in the empirical literature on learning from videos, and as such, an up-to-date review is needed.

Poquet et al. (2018) released preliminary findings of a systematic review of 178 papers concerning student learning from video in higher education and professional learning. This review presented a broad overview of the state of the literature, highlighting the trends in experimental design and large-scale data analysis studies. It found that manipulation of various design characteristics or learning activities can affect learning outcomes. However, Poquet et al. reported only on a small number of design principles and included studies on the use of videos without comparing designs. As a result, the current review adds to this work by including studies beyond the tertiary sector, isolating studies that compare video designs and reporting on a wider range of resulting design principles.

More recently, Castro-Alonso et al. (2019) completed a systematic meta-analysis of research into static versus dynamic animations. They found that overall dynamic visualisations were more effective than static media, but with a smaller effect size than that found by Höffler and Leutner (2007) of $g+ = 0.23$. While Castro-Alonso et al. concluded that instructional videos can be effective learning tools, their paper did not isolate specific principles of design, a key feature of this review.

The contribution of this review

While a small number of reviews have been completed in this field, none since Höffler and Leutner (2007) have isolated the impact of video design characteristics on learning outcomes, and even that review was restricted to experimental designs. These reviews provide a rich description of the types of instructional videos in use, the value of instructional videos as learning media, and their pedagogical applications. However, in order to facilitate research into effective design of these instructional videos, there is a need for a review of the broad range of literature on the impact of variations in video design on learning. Such literature exists across the full range of educational contexts (K-12, tertiary, adult, professional) and has been conducted with a variety of methodologies. The current paper provides a systematic review of this broad body of research, with the primary goal of identifying the design principles that foster effective instructional videos. In the same vein as Kimball (2013), we define design principles to be generalisable heuristics that are justified through empirical observations – offering guidelines for instructional design decisions. Interestingly, Kimball (2013) also noted that while principles are generalisable, they are also contingent, reminding us that they are not immutable. Mayer (2014) described this as *boundary conditions*, that is, the circumstances in which a design principle is more or less effective.

CTML

The effectiveness of instructional videos has been studied from a variety of perspectives. For example, Kay (2012) evaluated the impact of video use on test scores and cognitive engagement but also on student affect and attendance data. However, a large proportion of the research in the field, including 88 of the 113 papers included in the present review, draws on CTML, or the related work of cognitive load theory (CLT). CTML provides a useful lens through which to analyse instructional efficiency because it seeks to create specific principles of design, which can be useful when evaluating the effectiveness of instructional videos. In this context effectiveness relates to fostering learning, that is, the construction of knowledge (mental representations) which may be recalled (also described as retention) and/or applied to new contexts (also described as transfer) (Mayer, 2014). As a result, the CTML lens offers two goals for multimedia design: to improve remembering and understanding.

CTML (Mayer, 2014) is a theory of human cognitive architecture that emerged from CLT (Sweller et al., 2019) and dual coding theory (Paivio, 1971) in the late 1990s and has been influential in multimedia design since. Mayer's theory suggests that humans process information in two streams, verbal and visual, which are subsequently integrated with each other and incorporated into long-term memory. Each stream is initially independent, meaning humans usually learn better from a combination of words and pictures than either alone (Mayer, 2014). The creation of working mental models in long-term memory, which is how CTML defines learning, is not automatic but is based on the learner actively attending to elements in a multimedia presentation for example. Furthermore, the theory asserts that human working memory is very limited in capacity, and in order to assist learners in creating these working mental models, learning media should be designed in such a way as to avoid overwhelming that capacity, thus creating cognitive overload (Pollock et al., 2002). Researchers in the field of CTML have, over the past 20 years, established a range of design principles for the production of efficient multimedia learning materials.

While moderating factors such as prior learning and student motivation are considered by CTML, videos produced that adhere to the design principles established should theoretically result in more efficient learning gains than those that violate them. However, M. Wong et al. (2018) made the point that "instructional animation research has been extensive, but the results are inconsistent" (p. 446). For example, H. Lee and Mayer (2018) recently failed to replicate the redundancy and modality effects in learning from videos in a second language and suggested this established a boundary condition for the two principles. As previously mentioned, boundary conditions represent contexts or circumstances in which a design principle that has been shown to lead to greater learning gains fails to produce such an effect, or indeed impairs learning (Mayer, 2014). The degree to which all of these principles are applicable to instructional videos is not clear since much of the CTML literature assumes the principles apply equally to all forms of multimedia. Given the lack of coherence in much of the research relating to instructional video, there is a clear need to first identify which of the existing CTML principles are supported by the literature, particularly in relation to instructional videos, where boundary conditions may lie, and where new principles may have since been generated.

Method

This systematic review focuses on empirical research that compares different instructional video designs. Initial scoping of the literature revealed a range of research designs including experimental, quasi-experimental, case study and large data analysis methods. The diversity of research in the field and issues around consistency in terminology and reporting of impact (as discussed in the results) led us to the conclusion that there was insufficient consistency or volume of literature to support a comparison of effect sizes of the principles. Instead, it was clear that there was a need to first systematically describe the available research, namely (a) identify the CTML design principles that have been empirically tested in relation to instructional video and (b) identify the limitations within the literature that need to be addressed in order to strengthen future research. In doing so, this review provides much needed guidance to the field and especially for future research, facilitating a more coherent and consistent approach that will enable future comparative studies.

Search strategy

A total of 22 search strings based on existing CTML design principles and incorporating key terms related to instructional video design were developed (see Appendix A for a full list of these terms). Such a complex series of search strings was required because a preliminary search revealed that there is a lack of accepted nomenclature in the field regarding instructional video, and as a result it is hard to identify a corpus of relevant literature through simple search terms. For example, preliminary searches using the term *video* regularly returned results concerning video games. The search was conducted in April 2020 and again in June 2021 when the review process was being finalised to ensure more recent literature was also captured. ProQuest, ERIC and PsycInfo databases were used. A snowballing method was also employed, reviewing the reference lists of the selected papers for relevant papers that also matched the criteria.

Inclusion and exclusion criteria

This systematic review was conducted using the inclusion and exclusion criteria outlined in Table 1. For a study to be included, it needed to satisfy all of the inclusion criteria without violating any of the exclusion criteria. Crucially, studies needed to include results outlining learning from at least two video designs, where other contextual factors remained similar.

At times the process of determining whether the media used in a study counted as video was difficult. While the definition provided by Ibrahim et al. (2012) of video as "a stream of dynamic visual and auditory content" (p. 220) obviously includes playable media such as live video and dynamic animations and excluded static media, there were more problematic liminal cases. These included research in which a pedagogical agent's level of animation was studied, when an animation was controlled by the user, or 3D content in which the user's directional position determined the video content. These interactive media were excluded from this review because these interactive features suggest going beyond the definition of video (i.e., "stream of"), that is, the typical linear nature of a traditional video – and as such, different cognitive processes may be employed. Other media that was like an instructional video but functionally different enough to be excluded included media such as live feeds. Ultimately, this review was restricted to studies in which the media was a linear stream of dynamic and auditory content, with user controls limited to play, pause, back and forward, if present at all.

A decision to exclude papers with a focus on learning English as a Foreign Language (EFL) was based on the understanding that learning in a primary language is a cognitively different process to learning in a second language (Paas & Sweller, 2014). In recent research, H. Lee and Mayer (2018) suggest that learning from videos in a second language represents a boundary condition for the modality and redundancy principles. The authors conclude that more research is required in relation to the role of language proficiency, second language decoding and the interactions of these with instructional design principles. As a result, we considered it prudent to exclude EFL studies because they may introduce confounding contextual factors. For similar reasons, we also chose to exclude studies involving learners with cognitive disability and studies of an early childhood context.

Table 1
Inclusion and exclusion criteria

Inclusion criteria	**Exclusion criteria**
• Instructional videos • Peer-reviewed empirical research written in English • Paper focused on learning from videos • Reported empirical results comparing video designs	• VR videos, static media only, video conferencing • Early learning, EFL or language learning, or special education contexts • Meta analyses and reviews

Search results

These searches returned 1434 papers and conference proceedings. The first two named authors of this article reviewed 10% of the articles independently and differences were negotiated until 100% agreement was reached. Following this, the first named author completed the article selection. After reviewing titles and abstracts, 1152 were excluded due to the context of the study being other than instructional videos (649); a focus on video games (49); an EFL focus (30); an early childhood focus (4); a special needs focus (1); the paper printed in a language other than English (8); and duplicates (411). This left 282 full-text papers to review.

During a close analysis of these full texts, a further 177 were excluded due to a lack of empirical findings, such as proposals or theory papers (22); methodologies that did not compare video designs (55); non-video multimedia type (98); and an inability to source full-text copies (2). During this process, 8 additional papers were identified in the references of the included articles. This led to 113 papers being included in this study and which were then coded using NVivo software (version 12.2).

Coding

The aim of this paper is to identify the design principles for instructional video supported in the literature. To achieve this, the paper is particularly guided by the lens of CTML (Mayer, 2014). Therefore, we used Mayer's (2014) list of 15 principles as an a priori coding scheme. The constant comparative method (Boeije, 2002) was used to ensure that each paper was either coded to one or more existing principles (as *replicate, fail,* or *modify)* or that new codes were added or adapted when papers revealed new principles. The constant comparative method is described by Glaser and Strauss (1967) as a systematic method for simultaneous coding and analysis for the purpose of "generating and plausibly suggesting… categories, properties and hypotheses" (p. 104). Following the methods of Glaser and Strauss, we would, when necessary, generate a new code based on the new principle but then constantly compare each subsequent paper with the whole coding scheme. The new codes were further adapted, and theoretical properties expanded as necessary when subsequent papers were found to be working with similar variables.

The lack of consistent nomenclature in the research meant that it was not uncommon for studies to be working on similar variables and even ostensibly testing the same principles, but with different terminology. For all of these instances, the constant comparative method was employed to increase confidence in the robustness of the coding. The coding of the papers was conducted by the first named author of this article. The generation of new codes (principles) and their descriptions were negotiated with one of the other authors of this article, who employed the same comparative method. The naming convention of the new principles was such that the terminology was adopted from the first study to identify the paper. However, in line with Glaser and Strauss' (1967) method, when subsequent papers were found to be dealing with the same principle, the properties of both papers were considered and, if necessary, the title adapted to ensure both studies were accurately represented. The naming of the principles was also guided by the need to be clear and intuitive for readers.

In addition to coding each paper for design principles, we also captured details about the research design (e.g., experimental, participant demographics), the video design (e.g., type of video) and findings. These supported analysis of the principles as well as a broader discussion of research field. Details of the coding scheme are outlined in Appendix B, while results are outlined in Appendix C.

Results and discussion

This section reports on the state of the literature and the principles of video design that emerge. Because of the nature of the research field, which includes experimental and quasi-experimental studies, it is not possible to confidently report on the relative strength of each principle. Instead, this review identifies the principles that are supported in the literature and the issues which need to be addressed by the field, including critical questions of nomenclature and research design.

Characteristics of the sample

The review sample consisted of 113 peer-reviewed studies, each reporting empirical findings on at least one principle of video design and its effect on learning. The selected studies were published between 1992 and 2021, but only 17 were published before 2008, indicating an increasing interest in video design over the past decade. The rise of YouTube has possibly had an influence on this growing attention, with 23 of the studies making direct reference to the platform.

Principles of video design

This review began with an a-priori list of 15 CTML principles drawn from Mayer's (2014) work, which is arguably a seminal reference point for CTML studies. Mayer's list is not exhaustive, but it provides a useful initial coding structure in a field with varying nomenclature. Using the constant comparative method, a further 16 principles emerged from the subsequent research literature. Table 2 outlines the resulting 31 principles, with those included on Mayer's (2014, p. 63) representative list marked with an asterisk. Notably, three principles that appear on Mayer's list (*temporal contiguity*, *voice* and *drawing*) have not been the focus of any studies in which video is the instructional media. Like Mayer, the principles in our table are divided into three groups depending on the type of cognitive processing theoretically affected by each. Principles that reduce the amount of distracting information are coded as *extraneous processing*, those dealing with improving delivery of the core learning goal and coded as *essential processing*, while those dealing with improving the student's deep engagement with the material are coded as *generative processing* (see Mayer, 2014, p. 60).

In each row, the total number of papers that discuss the given principle is reported (*total*). Additionally, we include the number of papers that report a successful replication (replicate), a failure to replicate (fail) or a modification of the principle (modify). Such modifications include boundary conditions or proposed changes to a principle's definition. For example, C.-Y. Chen (2016) found that some types of learner control led to better transfer performance than system paced instruction, while some types did not. The total number of findings across replicate, fail and modify may add up to more than the total articles coded, due to multiple findings in one publication across experiments, or for different learner types. Each principle is given a number for easy reference in subsequent tables.

Table 2
Description of design principles and count of papers coded to each

	Extraneous processing principles	**Description of design technique**	**Total[a]**	**Replicate**	**Fail**	**Modify**
1	Coherence[b]	Only instructional material directly related to the key learning goal should be included.	10	8	2	2
2	Signalling[b]	Important information should be highlighted to learners.	13	10	6	5
3	Redundancy[b]	Written text should not be added when narration is present.	13	5	8	6
4	Spatial contiguity[b]	Related elements should be presented in close physical proximity on the screen (also called split attention).	3	3	-	-
5	Temporal contiguity[b]	Related elements (e.g., narration and visuals) should be presented at the same time.	-	-	-	-
6	Segmenting[b]	Longer videos should be broken into meaningful chunks.	13	10	3	2

7	Background music	Avoid including distracting background music.	3	2	2	2
8	Audio quality	Audio should be clear, with no distracting hissing or interference	2	2	1	-
9	Video length reduction	Shorter videos are more effective than long ones.	10	10	1	-
10	Perspective (1st superior)	Videos shot from the learner's perspective are more effective than third-person perspective.	1	1	-	-
11	Presenter's face	Avoid including the presenter's face when alternative visuals are displayed.	7	1	2	5
12	Sound effects	Avoid including sound effects.	1	1	1	-
Essential processing principles						
13	Pre-training[b]	Learners should be introduced to key names and characteristics before the lesson.	2	2	-	-
14	Modality[b]	Use spoken narration rather than written text.	13	6	9	2
15	Multimedia[b]	Use words and pictures rather than words alone.	2	2	-	-
16	Speech rate (fast superior)	Speech rate should be faster than conversational speaking rate.	2	2	1	1
17	Transience	Video loses advantages over static media when too much information is presented too quickly.	6	4	3	-
18	Worked example	Include completed guidance or examples when solving problems or learning skills.	3	2	1	-
19	Learner control	Students should be given control over playback.	18	13	4	5
20	Reviews	Videos should end with a summary of the content.	3	3	-	-
Generative processing principles						
21	Personalisation[b]	Narrations should use first/second person conversational speech.	6	4	3	2
22	Voice principle[b]	Narrations should be recorded in a human voice rather than synthesised, machine voice.	-	-	-	-
23	Embodiment principle[b]	Videos should include human movement or gestures, such as showing hands when assembling.	11	8	4	4
24	Guided discovery[b]	Interface should provide hints and feedback as learner solves problems.	1	0	1	-
25	Self-explanation[b]	Videos should prompt students to explain the learning goal to themselves.	4	2	2	
26	Drawing[b]	Leaners should be encouraged to draw the learning goals.	-	-	-	-
27	Dialogue	Videos that show dialogue between an instructor and learner outperform straight declarative videos.	2	2	-	-
28	Emotional design	Warm, high-saturation colours and anthropomorphisms should be used in videos.	4	3	3	3
29	Misconceptions	Conceptual videos should dispel common misconceptions at the start.	2	2	-	-
30	Integrated learning activities	Integrate practice activities, either during pauses in the presentation or following the video.	7	7	-	3
31	Interactivity	Videos that include learner controllable content outperform standard playable video.	4	3	1	1

[a] All papers are listed in Appendix C.
[b] Principles found in Mayer (2014, p. 63).

In conducting this review, it was observed that the principles can encompass a range of design interventions. For example, *signalling* (also referred to as cueing or attention guiding in the literature) can describe shading or illuminating key content (de Koning et al., 2011), including an arrow to guide attention (L. Lin et al., 2016), gradually revealing or animating detail (Fiorella & Mayer, 2016) or guiding text (Boucheix & Guignard, 2005). At the same time, some design interventions, such as *presenter's face*, could conceivably be included under spatial contiguity. However, the presence of the presenter's face has attracted considerable interest in the literature and has been identified as a principle in its own right in seven of the papers. Nevertheless, the way in which principles can contain a range of substantially different implementations and the reality that some implementations could be impacting on more than one principle suggest that these principles cannot yet be "mechanically applied to guarantee a satisfactory educational outcome" (Lowe & Schnotz, 2014, p. 536).

Due to word count restrictions of this article, discussion of the individual principles is necessarily limited, and readers are encouraged to consult Appendix C for more details. Therefore, the following sections identify notable findings from the review: principles that appear to be most supported in the literature, principles that are highly confounded, and principles that have been relatively under-studied.

Principles of instructional video design with strong support in the literature

To identify which of the principles in Table 2 have the strongest support in the literature, both replications and the number of studies focusing on that principle were considered. Six of the principles were studied at least six times and were replicated in twice as many studies as they failed. These represented the principles with the strongest support.

Coherence was found to be an effective principle in contexts ranging from secondary students studying aquaplaning in cars (Kulgemeyer, 2018) to tertiary students learning about immunology (Mayer et al., 2008). Only D. Ozdemir and Doolittle's (2015) study failed to replicate the effect, and even then only in one out of the two experiments reported on in the article. This wide range of contexts suggests that the benefit of coherence is not tied to particular age groups or subject domains. The practice of *integrating learning* activities was investigated in 7 studies, all of which found that students who completed learning activities in addition to watching a video outperformed students who watched the video only. Interestingly, Szpunar et al. (2014) found that interpolating tests throughout video-viewing not only improved performance but also improved accuracy of student perception of learning. The *embodiment principle* also had support in the literature, in diverse contexts such as primary mathematics (Cook et al., 2016) and tertiary writing classes (C.-M. Chen & Wu, 2015). *Learner control*, mostly through the use of pause and play buttons and scrubbing control (the sliding position controller included in most video playback platforms), has also been shown to be effective in a range of contexts, as has the integration of learning activities throughout video playback.

Finally, the principles of *video length reduction* and *segmentation* were found to have strong support based on the criteria outlined, and producers should be encouraged to adopt these principles of design. While the two principles both call for short videos, they differ in that while video length reduction suggests the overall time should be reduced, segmentation points to a practice of cutting longer videos into shorter meaningful chunks. In most circumstances, shorter videos lead to greater learning gains than longer ones. Guo et al. (2014) suggest this is due both to the elimination of extraneous material but also due to more precise and efficient explanations. While they identified 6 minutes as a key threshold for keeping student engagement in their analysis of MOOC data, more research is needed to investigate whether different age groups or subject domains have specific duration thresholds. Likewise segmenting, the process of breaking long videos into shorter sections, was found to be near universally effective in improving learning, with 10 of 12 studies reviewed reporting positive gains, and the remaining two reporting no difference.

Principles of instructional video design with confounding findings

A number of principles were shown to have a weaker ratio of replications to failures and consequently invite a degree of caution. Again, due to length limitations, we focus on those principles that have been studied six or more times. Some principles that hold up to scrutiny when applied to other multimedia types are confounded when applied to the special case of video design, notably modality and redundancy. Importantly, this held true across methodologies and video types. Low and Sweller (2014) suggested that the modality effect may be eliminated when learning from long or complex materials, but this review found that long media duration was not a factor. For example, Chung et al. (2015) did not find an effect of modality using a 40-second animation, while Leahy and Sweller (2016) did find an effect using a 663-second animation. Similar mixed results were found when examining the literature concerning redundancy. Indeed, eight studies failed to find any negative learning effect of including text or subtitles in addition to animation. Moreover, some participants reported using captions as a guide to note-taking (Adegoke, 2010) or a way of confirming what the instructor said (M. Ozdemir et al., 2016), suggesting they may at times have a useful function. These mixed results suggest more research needs to be completed to identify the boundary conditions of these principles, which may lie in the transience of video media or other principles beyond length or video type.

The matter of whether to include a presenter's face in an instructional video was reported in seven papers, but these yielded a range of findings, out of which no reliable pattern emerged regarding when the social presence of a presenter's face outweighs the spatial contiguity or split attention effect. Further research is needed to determine if there are boundary conditions for this practice.

Principles under-represented in research

Six of the principles identified in Mayer's (2014, Chapter 3) representative list as effective for general multimedia design were studied in two or fewer papers where the instructional media is an instructional video. Considering the increasing ubiquity of instructional videos in educational contexts, it is surprising that these principles, such as the *voice principle* (no studies), *drawing principle* (no studies), *guided discovery* (one study), *pre-training* (two studies) and the *multimedia principle* itself (two studies) have been applied to videos so rarely.

Finally, a further nine principles have emerged in this literature review, but cannot be considered as well supported, because they have been investigated in three or fewer studies. These include issues common to all video designers, such as the role of audio quality (Tan and Pearce, 2011), speech rate (Guo et al., 2014) and background music (Moreno & Mayer, 2000). They also include more nuanced matters of pedagogical design, such as the *misconception effect* (Muller, Bewes et al., 2008), and the inclusion of reviews at the conclusion of videos (van der Meij, 2017). More research is required to determine whether these principles are reliable, and the theoretical impact, if any, of their impact on learning from videos.

Challenges in the literature

A considerable challenge in conducting this review stemmed from efforts to reconcile the wide variety of media, methodologies, subject matters, definitions of terms and learner ages in the literature. Furthermore, a number of papers failed to adequately describe the media or the procedure used in the study. The following sections outline the strengths and weaknesses of the current literature as encountered in this review.

Limited comparability

The majority of the studies in this review reported on controlled experiments (77), while the remaining studies were made up of quasi-experimental designs (30), case studies (4) and mixed methods designs (3). Of these studies, only 52 reported an effect size. This limits the ability to judge comparative strengths of the principles. However, as will be discussed in the following sections, the inconsistency in nomenclature, gaps in reporting of intervention variables and other limitations cast a shadow over the reliability of such a comparative approach within this relatively small field.

A need for replication from experimental to naturalistic settings

A problem in translating experimental findings to real practice is found in the wide range of arguably unrealistic learning conditions placed on participants in experimental conditions. For example, Stull et al. (2018) studied the effect of using transparent whiteboards, and Jadin et al. (2009) studied the effect of subtitles. Both studies showed participants a 20-minute lecture video, but neither set of participants were permitted to take any notes. It is standard practice for students to take notes during lectures to offload the cognitive load associated with trying to process new information and to encourage the generative load associated with the drawing principle (Mayer, 2014, Chapter 3). Similarly, experiments investigating the instructional efficiency of practical instructional videos, such as tying knots, often prevent learners from practising during instruction (e.g., Marcus et al., 2013). It seems unlikely that a learner in a setting outside this experimental context would refrain from touching the rope while viewing a video on how to tie it. Van der Zee et al. (2017) studied a variety of designs for MOOC videos but prevented students from having control over the pace of viewing using play, pause and scrubbing. MOOC platforms regularly allow scrubbing, and learner control has been found to have a moderating effect on learning (Höffler & Schwartz, 2011; Kühl et al., 2014).

While these conditions are defensible from a methodological perspective – because they limit confounding variables – it means that caution should be used when applying the resulting findings to contextually different learning situations (Persson et al., 2019). A possible solution to this problem was demonstrated by Merkt et al. (2011), who replicated their experimental study of various levels of video interactivity in a quasi-experimental secondary school setting. Such complementary replications of experimental studies in authentic educational contexts can help establish support for the design principles and define boundary conditions (Butcher, 2014). Despite this, Merkt et al. (2011) were the only researchers in the 113-paper sample to adopt such a complementary replication method.

Measures of learning – recall vs transfer

Measures of learning were inconsistent across the studies, with various combinations of direct recall of knowledge, transfer (applying knowledge to novel problems), and proficiency (ability to replicate a practical skill). *Proficiency* is a term we have used to describe a variety of terms used in the literature, such as *ability to perform* (Bobrow et al., 2011; Schmitz et al., 2018), *reproduce* (Biard et al., 2018; Hatsidimitris & Kalyuga, 2013) and *construct* (Castro-Alonso et al., 2015) with specific reference to practical skills. We have taken this step to separate these studies from those that simply ask learners to recall, as defined by Mayer (2014): "ability to reproduce or recognise presented material" (p. 20). There is of course an argument to consider proficiency a type of recall or transfer; however, we believe proficiency is different in that the learner is not simply reproducing information but translating it in terms of practical skills. As shown in Appendix C, 32 studies relied only on immediate recall of knowledge, despite Stull et al. (2018) finding that a treatment that had a significant effect on immediate recall had not persisted after a 7-day delay. This indicates that there are serious questions concerning the worth of immediate recall tests alone. Studies that included both recall and transfer often found that principles affected one but not the other. Mayer's (2014) argument that learning is the creation of working mental models suggests that these models are useful when they can be applied to novel situations. Like Sweller et al. (2019) and Mayer (2018), we argue that future experimental studies should include transfer, and preferably delayed transfer, measures.

Poor description of media – a need for a standard

In order to facilitate replication in research about learning from videos and to allow for meaningful meta-analysis, there is a need for a standard method of describing the actual videos used and the means by which learners view them. While some papers described the media thoroughly, including screenshots and descriptions of the technology employed, many did not. Of the 113 studies, 21 failed to report the duration of the videos used, 20 failed to report on the level of learner control allowed, seven failed to report on how the students viewed the video, and in eight cases, we were unable to determine the video type because the description was inadequate. The findings of this review show these variables to be important moderators of student learning, and a standard format of describing a video would help to avoid such omissions. Kay (2012) experienced similar frustration when completing a review of video podcasts and also called for clearer descriptions of videos used.

It would be unrealistic to expect researchers to report on every possible design feature of a video. For this reason, research reporting on videos should wherever possible allow readers to view the video itself, via a link to an online version. This would allow authors to conduct secondary analyses and comparisons of findings. For example, while they did not report on the audio quality of their videos, both Kay and Edwards (2012) and Umutlu and Akpinar (2020) included hyperlinks to their videos within the article text. This allowed us to evaluate the audio quality and judge that it was relatively poor in both, when compared with many professionally produced videos. Audio quality has been established as an important principle of instructional design (Kühl et al., 2014; Newman & Schwarz, 2018), and had other researchers also included links to their worked example videos, some meta-analysis of audio quality on learning may be possible. We propose that the inclusion of a link to the actual video used is the optimal way to communicate the video design.

The diversity of video styles – can they be compared?

It is unlikely that a video could be created that displays characteristics of one principle, while excluding any moderating influence of others. In other words, while in a single experiment, video A and video B may vary only with regard to one target principle (such as the speech rate), the video design will necessarily satisfy and violate other principles (like coherence), which may or may not act as moderators to the target principle. A second experiment that focuses on the same target principle may report different findings, as a result of another element of the video design that may not be reported. Because few videos studied are publicly available and design elements are rarely described adequately, it is hard for the reader to compare seemingly conflicting findings. For example, Izmirli and Kurt (2016) found no effect of learner control on tertiary students studying computer science, using a video lasting 22 minutes, while Höffler and Schwartz (2011) found learner control to improve the learning of secondary students using a 73-second video on surfactants. It is difficult to conclude whether the conflicting findings are the result of the video duration, the demographic, the subject domain, or some other unreported design characteristic like speech rate, accent, or degree of complexity. This should not be seen as a fatal flaw in studying video design, but as a further call for the publishing of videos to allow for replications.

Conclusion

Instructional videos are a common feature of contemporary educational contexts and therefore there is a need to consider what principles lead to effective learning outcomes. CTML offers a broad range of design principles for learning media creation. However, these principles have been largely developed from research using instructional media other than videos. Educators need to question whether the principle being applied is appropriate to the specific media they use and context they find themselves in. Until now, there has been no comprehensive list of principles that have been shown to improve learning specifically from instructional videos. This review provides a useful starting point for instructional video designers but also reveals a range of limitations in the current literature which need to be addressed in future research.

This review has identified 28 design principles featuring in empirical research. This consisted of 12 of Mayer's (2014, Chapter 3) original 15 principles, as well as 16 new principles. Importantly, this paper reveals that not all principles have a strong evidence base for improving learning. For example, the redundancy and modality principles appear to be variable in effect, whereas the principles of coherence, segmenting and learner control appear to be more robust, having been found to improve learning from instructional videos across a variety of contexts.

In particular, educators and producers of instructional videos are encouraged to keep videos short, to focus on one learning goal, to make learning goals explicit and, wherever possible, to give learners control over playback. Other principles of design, such as the inclusion of misconceptions, reviews, pre-training and the use of first-person perspective, have emerged but would benefit from a wider research base. Conversely, the principles of modality and redundancy, which have been well established in research using static media, returned mixed results in this review, suggesting they may not be applicable to instructional video design.

The review also revealed that the research field suffers from a lack of consistent nomenclature and reporting of media and research design. The multiplicity of video designs and the lack of clear descriptions of media used in studies makes it hard for readers to compare results, as design decisions may activate unreported principles. Similarly, variances in research design, including levels of learner control, screen types and media length have all been shown to impact learning, yet are not always reported or discussed.

Future research needs to test for these principles, accounting for boundary conditions and ideally replicating the studies in naturalistic settings. While CTML principles have been generally applied to all multimedia (Mayer, 2014, Chapter 3), this review suggests that delivering content via instructional videos may mediate these principles. While it is possible that the reason for this lies in the transitory nature of both the visual and audio information in videos (Leahy & Sweller, 2016), theoretical work may need to be conducted in further developing CTML to account for the specific phenomenon of learning from instructional videos. In short, while this review has identified the extent of support for the principles in the literature, more work is needed to establish why results differ in videos to other instructional media.

References

*References marked with an asterisk are included in the systematic review.

*Adegoke, B. A. (2010). Integrating animations, narratives and textual information for improving Physics learning. *Electronic Journal of Research in Educational Psychology*, *8*(2), 725–748. https://doi.org/10.25115/ejrep.v8i21.1391

*Afify, M. K. (2019). Effect of interactive video length within e-learning environments on cognitive load, cognitive achievement and retention of learning. *Turkish Online Journal of Distance Education*, *21*(4), 68–89. https://doi.org/10.17718/tojde.803360

*Ali, A. Z. M. (2010). Effects of teacher controlled segmented-animation presentation in facilitating learning. *Journal of Educational Multimedia and Hypermedia*, *19*(4), 367–378. https://www.learntechlib.org/primary/p/34544/

*Ali, A. Z. M. (2013). Effects of segmented-animation in projected presentation condition. *Journal of Educational Technology & Society*, *16*(3), 234–245. http://www.jstor.org/stable/jeductechsoci.16.3.234

Armstrong, A. W., Idriss, N. Z., & Kim, R. H. (2011). Effects of video-based, online education on behavioral and knowledge outcomes in sunscreen use: A randomized controlled trial. *Patient Education and Counseling*, *83*(2), 273–277. https://doi.org/10.1016/j.pec.2010.04.033

*Arnone, M. P., & Grabowski, B. L. (1992). Effects on children's achievement and curiosity of variations in learner control over an interactive video lesson. *Educational Technology Research and Development*, *40*(1), 15–27. https://doi.org/10.1007/BF02296702

*Austin, K. A. (2009). Multimedia learning: Cognitive individual differences and display design techniques predict transfer learning with multimedia learning modules. *Computers & Education*, *53*(4), 1339–1354. https://doi.org/10.1016/j.compedu.2009.06.017

*Barnes, S. R. (2016). Studies in the efficacy of motion graphics: the effects of complex animation on the exposition offered by motion graphics. *Animation*, *11*(2), 146–168. https://doi.org/10.1177/1746847716637823

*Biard, N., Cojean, S., & Jamet, E. (2018). Effects of segmentation and pacing on procedural learning by video. *Computers in Human Behavior*, *89*, 411–417. https://doi.org/10.1016/j.chb.2017.12.002

*Bobrow, B. J., Vadeboncoeur, T. F., Spaite, D. W., Potts, J., Denninghoff, K., Chikani, V., Brazil, P., Ramsey, B., & Abella, B. S. (2011). The effectiveness of ultrabrief and brief educational videos for training lay responders in hands-only cardiopulmonary resuscitation. *Circulation: Cardiovascular Quality and Outcomes*, *4*(2), 220–226. https://doi.org/10.1161/CIRCOUTCOMES.110.959353

Boeije, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Quality and quantity*, *36*(4), 391–409. https://doi.org/10.1023/A:1020909529486

*Boucheix, J.-M., & Forestier, C. (2017). Reducing the transience effect of animations does not (always) lead to better performance in children learning a complex hand procedure. *Computers in Human Behavior*, *69*, 358–370. https://doi.org/10.1016/j.chb.2016.12.029

*Boucheix, J.-M., & Guignard, H. (2005). What animated illustrations conditions can improve technical document comprehension in young students? Format, signaling and control of the presentation. *European Journal of Psychology of Education*, *20*(4), 369–388. https://doi.org/10.1007/BF03173563

Brame, C. J. (2016). Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE-Life Sciences Education*, *15*(4). https://doi.org/10.1187/cbe.16-03-0125

Butcher, K. R. (2014). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 174–205). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.010

*Castro-Alonso, J. C., Ayres, P., & Paas, F. (2015). Animations showing Lego manipulative tasks: Three potential moderators of effectiveness. *Computers & Education*, *85*, 1–13. https://doi.org/10.1016/j.compedu.2014.12.022

Castro-Alonso, J. C., Wong, M., Adesope, O. O., Ayres, P., & Paas, F. (2019). Gender imbalance in instructional dynamic versus static visualizations: a Meta-analysis. *Educational Psychology Review*, *31*(2), 361–387. https://doi.org/10.1007/s10648-019-09469-1

*Chang, H.-Y. (2017). How to augment the learning impact of computer simulations? The designs and effects of interactivity and scaffolding. *Interactive Learning Environments*, *25*(8), 1083–1097. https://doi.org/10.1080/10494820.2016.1250222

*Chen, C.-M., & Wu, C.-H. (2015). Effects of different video lecture types on sustained attention, emotion, cognitive load, and learning performance. *Computers & Education, 80*, 108–121. https://doi.org/10.1016/j.compedu.2014.08.015

*Chen, C.-Y. (2016). Cognitive support for learning computer-based tasks using animated demonstration. *Interactive Learning Environments*, *24*(4), 859–874. https://doi.org/10.1080/10494820.2014.936943

*Cheon, J., Chung, S., Crooks, S. M., Song, J., & Kim, J. (2014). An investigation of the effects of different types of activities during pauses in a segmented instructional animation. *Journal of Educational Technology & Society*, *17*(2), 296–306. https://drive.google.com/open?id=1ueDzPrT6TshCpMhLHnR7yJMo3FbxgdQl

*Cheon, J., Crooks, S., & Chung, S. (2014). Does segmenting principle counteract modality principle in instructional animation? *British Journal of Educational Technology*, *45*(1), 56–64. https://doi.org/doi.org/10.1111/bjet.12021

*Chien, Y.-T., & Chang, C.-Y. (2012). Comparison of different instructional multimedia designs for improving student science-process skill learning. *Journal of Science Education and Technology*, *21*(1), 106–113. https://doi.org/10.1007/s10956-011-9286-3

*Chung, S., Cheon, J., & Lee, K.-W. (2015). Emotion and multimedia learning: an investigation of the effects of valence and arousal on different modalities in an instructional animation. *Instructional Science*, *43*(5), 545–559. https://doi.org/10.1007/s11251-015-9352-y

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. Wiley. https://doi.org/10.1002/9781119239086

*Cook, S. W., Friedman, H. S., Duggan, K. A., Cui, J., & Popescu, V. (2016). Hand gesture and mathematics learning: lessons from an Avatar. *Cognitive Science*, *41*(2), 518–535. https://doi.org/doi.org/10.1111/cogs.12344

*Cooper, D., & Higgins, S. (2015). The effectiveness of online instructional videos in the acquisition and demonstration of cognitive, affective and psychomotor rehabilitation skills. *British journal of educational technology*, *46*(4), 768–779. https://doi.org/10.1111/bjet.12166

*Debuse, J. C., Hede, A., & Lawley, M. (2009). Learning efficacy of simultaneous audio and on-screen text in online lectures. *Australasian Journal of Educational Technology*, *25*(5), 748–762. https://doi.org/10.14742/ajet.1119

*De Boer, J., Kommers, P. A., & De Brock, B. (2011). Using learning styles and viewing styles in streaming video. *Computers & Education*, *56*(3), 727–735. https://doi.org/10.1016/j.compedu.2010.10.015

*de Koning, B. B., Tabbers, H. K., Rikers, R. M., & Paas, F. (2007). Attention cueing as a means to enhance learning from an animation. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition, 21*(6), 731–746. https://doi.org/10.1002/acp.1346

*de Koning, B. B., Tabbers, H. K., Rikers, R. M., & Paas, F. (2010). Attention guidance in learning from a complex animation: Seeing is understanding? *Learning and Instruction, 20*(2), 111–122. https://doi.org/10.1016/j.learninstruc.2009.02.010

*de Koning, B. B., Tabbers, H. K., Rikers, R. M., & Paas, F. (2011). Improved effectiveness of cueing by self-explanations when learning from a complex animation. *Applied Cognitive Psychology*, *25*(2), 183–194. https://doi.org/10.1002/acp.1661

*de Koning, B. B., van Hooijdonk, C. M., & Lagerwerf, L. (2017). Verbal redundancy in a procedural animation: On-screen labels improve retention but not behavioral performance. *Computers & Education, 107*, 45–53. https://doi.org/10.1016/j.compedu.2016.12.013

*Delen, E., Liew, J., & Willson, V. (2014). Effects of interactivity and instructional scaffolding on learning: Self-regulation in online video-based environments. *Computers & Education*, *78*, 312–320. https://doi.org/10.1016/j.compedu.2014.06.018

*Dousay, T. A. (2016). Effects of redundancy and modality on the situational interest of adult learners in multimedia learning. *Educational Technology Research and Development*, *64*(6), 1251–1271. https://doi.org/10.1007/s11423-016-9456-3

*Dunsworth, Q., & Atkinson, R. K. (2007). Fostering multimedia learning of science: Exploring the role of an animated agent's image. *Computers & Education*, *49*(3), 677–690. https://doi.org/10.1016/j.compedu.2005.11.010

*Fanguy, M., Costley, J., Baldwin, M., Lange, C., & Wang, H. (2019). Diversity in video lectures. *The International Review of Research in Open and Distributed Learning*, *20*(2). https://doi.org/10.19173/irrodl.v20i2.3838

*Fiorella, L., & Mayer, R. E. (2016). Effects of observing the instructor draw diagrams on learning from multimedia messages. *Journal of Educational Psychology, 108*(4), 528–546. https://doi.org/10.1037/edu0000065
*Fiorella, L., van Gog, T., Hoogerheide, V., & Mayer, R. E. (2017). It's all a matter of perspective: Viewing first-person video modeling examples promotes learning of an assembly task. *Journal of Educational Psychology*, *109*(5), 653–665. https://doi.org/10.1037/edu0000161
*Fountoukidou, S., Ham, J., Matzat, U., & Midden, C. (2019). Effects of an artificial agent as a behavioral model on motivational and learning outcomes. *Computers in Human Behavior, 97,* 84–93. https://doi.org/10.1016/j.chb.2019.03.013
Fyfield, M. (2020). Selection of instructional videos by secondary teachers: Knowledge and context. [Doctoral dissertation, Monash University]. https://doi.org/10.26180/13697608.v1
*García-Rodicio, H. (2014). Support for learning from multimedia explanations. A comparison of prompting, signaling, and questioning. *Journal of Educational Computing Research, 50*(1), 29–43. https://doi.org/10.2190/EC.50.1.b
*Garland, T., & Sanchez, C. A. (2013). Rotational perspective and learning procedural tasks from dynamic media. *Computers & Education, 69*, 31–37. https://doi.org/10.1016/j.compedu.2013.06.014
Glaser, B. G. & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine DeGruyter.
*Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement: An empirical study of MOOC videos. In *Proceedings of the First ACM Conference on Learning@Scale Conference* (pp. 41–50). Association for Computing Machinery. https://doi.org/10.1145/2556325.2566239
*Haagsman, M. E., Scager, K., Boonstra, J., Koster, M. C. (2020). Pop-up questions within educational videos: effects on Students' Learning. *Journal of Science Education and Technology, 29*, 713–724. https://doi.org/10.1007/s10956-020-09847-3
*Hasler, B. S., Kersten, B., & Sweller, J. (2007). Learner control, cognitive load and instructional animation. *Applied Cognitive Psychology, 21*(6), 713–729. https://doi.org/10.1002/acp.1345
*Hatsidimitris, G., & Kalyuga, S. (2013). Guided self-management of transient information in animations through pacing and sequencing strategies. *Educational Technology Research and Development, 61*(1), 91–105. https://doi.org/10.1007/s11423-012-9276-z
Henderson, M., Selwyn, N., & Aston, R. (2017). What works and why? Student perceptions of 'useful'digital technology in university teaching and learning. *Studies in Higher Education, 42*(8), 1567–1579. https://doi.org/10.1080/03075079.2015.1007946
Hobbs, R. (2006). Non-optimal uses of video in the classroom. *Learning, Media and Technology, 31*(1), 35–50. https://doi.org/10.1080/17439880500515457
Höffler, T. N., & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction, 17*(6), 722–738. https://doi.org/10.1016/j.learninstruc.2007.09.013
*Höffler, T. N., & Schwartz, R. N. (2011). Effects of pacing and cognitive style across dynamic and non-dynamic representations. *Computers & Education, 57*(2), 1716–1726. https://doi.org/10.1016/j.compedu.2011.03.012
Hollands, F. M., & Tirthali, D. (2015). *MOOCs in higher education: Institutional goals and paths forward*. Palgrave Macmillan.
*Ibrahim, M., Antonenko, P. D., Greenwood, C. M., & Wheeler, D. (2012). Effects of segmenting, signalling, and weeding on learning from educational video. *Learning, Media and Technology, 37*(3), 220–235. https://doi.org/10.1080/17439884.2011.585993
*Ibrahim, M., Callaway, R., & Bell, D. (2014). Optimizing instructional video for preservice teachers in an online technology integration course. *American Journal of Distance Education, 28*(3), 160–169. https://doi.org/10.1080/08923647.2014.924697
*Izmirli, S., & Kurt, A. A. (2016). Effects of modality and pace on achievement, mental effort, and positive affect in multimedia learning environments. *Journal of Educational Computing Research, 54*(3), 299–325. https://doi.org/10.1177/0735633115621921
*Jadin, T., Gruber, A., & Batinic, B. (2009). Learning with e-lectures: The meaning of learning strategies. *Educational Technology & Society, 12*(3), 282–288.
*Jung, J., Kim, D., & Na, C. (2016). Effects of WOE presentation types used in pre-training on the cognitive load and comprehension of content in animation-based learning environments. *Educational Technology & Society, 19*(4), 75–86. https://drive.google.com/open?id=1nuUxYdnZQo5SLkgKS-ohUjAPerSi8Im1

Kay, R. H. (2012). Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior*, *28*(3), 820–831. https://doi.org/10.1016/j.chb.2012.01.011
*Kay, R. H., & Edwards, J. (2012). Examining the use of worked example video podcasts in middle school mathematics classrooms: A formative analysis / Étude sur l'utilisation de podcasts d'exemples pratiques dans des classes de mathématiques à l'école secondaire de premier cycle. *Canadian Journal of Learning and Technology / La revue canadienne de l'apprentissage et de la technologie*, *38*(3), 1–20. https://doi.org/10.21432/T2PK5Z
*Kim, J., Guo, P. J., Seaton, D. T., Mitros, P., Gajos, K. Z., & Miller, R. C. (2014). Understanding in-video dropouts and interaction peaks in online lecture videos. In *Proceedings of the First ACM Conference on Learning@Scale Conference* (pp. 31–40). Association for Computing Machinery. https://doi.org/10.1145/2556325.2566237
Kimball, M. A. (2013). Visual design principles: An empirical study of design lore. *Journal of Technical Writing and Communication*, *43*(1), 3–41. https://doi.org/10.2190/TW.43.1.b
*Kizilcec, R. F., Bailenson, J. N., & Gomez, C. J. (2015). The instructor's face in video instruction: Evidence from two large-scale field studies. *Journal of Educational Psychology, 107*(3), 724–739. https://doi.org/10.1037/edu0000013
*Kopiez, R., Platz, F., & Wolf, A. (2013). The overrated power of background music in television news magazines: A replication of Brosius' 1990 study. *Musicae Scientiae*, *17*(3), 309–331. https://doi.org/10.1177/1029864913489703
*Kühl, T., Eitel, A., Damnik, G., & Körndle, H. (2014). The impact of disfluency, pacing, and students' need for cognition on learning with multimedia. *Computers in Human Behavior, 35*, 189–198. https://doi.org/10.1016/j.chb.2014.03.004
*Kulgemeyer, C. (2018). A framework of effective science explanation videos informed by criteria for instructional explanations. *Research in Science Education*, 1–22. https://doi.org/10.1007/s11165-018-9787-7
*Laws, P. W., Willis, M. C., Jackson, D. P., Koenig, K., & Teese, R. (2015). Using research-based interactive video vignettes to enhance out-of-class learning in introductory physics. *The Physics Teacher*, *53*(2), 114–117. https://doi.org/10.1119/1.4905816
*Leahy, W., & Sweller, J. (2016). Cognitive load theory and the effects of transient information on the modality effect. *Instructional Science, 44*(1), 107–123. https://doi.org/10.1007/s11251-015-9362-9
Lee, H., & Mayer, R. E. (2018). Fostering learning from instructional video in a second language. *Applied Cognitive Psychology, 32*(5), 648–654. https://doi.org/10.1002/acp.3436
*Lee, S., & Lang, A. (2015). Redefining media content and structure in terms of available resources: Toward a dynamic human-centric theory of communication. *Communication Research, 42*(5), 599–625. https://doi.org/10.1177/0093650213488416
*Lin, L., Atkinson, R. K., Savenye, W. C., & Nelson, B. C. (2016). Effects of visual cues and self-explanation prompts: empirical evidence in a multimedia environment. *Interactive Learning Environments*, *24*(4), 799–813. https://doi.org/10.1080/10494820.2014.924531
*Lin, Y.-C., Shen, M.-H., & Liu, C.-J. (2015). A research of employing cognitive load theory in science education via web-pages. *International Journal of Online Pedagogy and Course Design*, *4*(2), 19–34. https://doi.org/10.4018/ijopcd.2014040102
*Liu, R., Relan, A., & Napolitano, J. (2020). The efficiency of online "inked" videos versus recorded PowerPoint lectures on teaching pathophysiology to medical students in pre-clerkship years: A pilot study. *Journal of Medical Education and Curricular Development, 7*, 1–6. https://doi.org/10.1177/2382120519897031
Low, R., & Sweller, J. (2014). The modality principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 227–246). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.012
Lowe, R., & Schnotz, W. (2014). Animation principles in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 513–546). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.026
Lucas, T., & Abd Rahim, R. (2017). The similarities and nuances of explicit design characteristics of well-received online instructional animations. *Animation, 12*(1), 80–99. https://doi.org/10.1177/1746847717690671
*Lynch, K., Barr, N., & Oprescu, F. (2012). Learning paramedic science skills from a first person point of view. *Electronic Journal of e-Learning, 10*(4), 396–406.

*Marcus, N., Cleary, B., Wong, A., & Ayres, P. (2013). Should hand actions be observed when learning hand motor skills from instructional animations? *Computers in Human Behavior*, *29*(6), 2172–2178. https://doi.org/10.1016/j.chb.2013.04.035
*Mautone, P. D., & Mayer, R. E. (2001). Signaling as a cognitive guide in multimedia learning. *Journal of Educational Psychology, 93*(2), 377–389. https://doi.org/10.1037/0022-0663.93.2.377
Mayer, R. E. (Ed.). (2014). *The Cambridge handbook of multimedia learning*. Cambridge University Press. https://doi.org/10.1017/CBO9781139547369
*Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93*(2), 390–397. https://doi.org/10.1037/0022-0663.93.2.390
*Mayer, R. E., Fennell, S., Farmer, L., & Campbell, J. (2004). A personalization effect in multimedia learning: Students learn better when words are in conversational style rather than formal style. *Journal of Educational Psychology, 96*(2), 389–395. https://doi.org/10.1037/0022-0663.96.2.389
Mayer, R. E., Fiorella, L., & Stull, A. (2020). Five ways to increase the effectiveness of instructional video. *Educational Technology, Research and Development, 68*, 837–852. https://doi.org/10.1007/s11423-020-09749-6
*Mayer, R. E., Griffith, E., Jurkowitz, I. T., & Rothman, D. (2008). Increased interestingness of extraneous details in a multimedia science presentation leads to decreased learning. *Journal of Experimental Psychology: Applied, 14*(4), 329≠339. https://doi.org/10.1037/a0013835
*Mayer, R. E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology*, *93*(1), 187–198. https://doi.org/10.1037/0022-0663.93.1.187
*Mayer, R. E., Mathias, A., & Wetzell, K. (2002). Fostering understanding of multimedia messages through pre-training: Evidence for a two-stage theory of mental model construction. *Journal of Experimental Psychology: Applied, 8*(3), 147–154. https://doi.org/10.1037//1076-898X.8.3.147
Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. *Journal of Educational Psychology, 91*(2), 358–368. https://doi.org/10.1037/0022-0663.91.2.358
*Merkt, M., Ballmann, A., Felfeli, J., & Schwan, S. (2018). Pauses in educational videos: Testing the transience explanation against the structuring explanation. *Computers in Human Behavior, 89*, 399–410. https://doi.org/10.1016/j.chb.2018.01.013
*Merkt, M., Weigand, S., Heier, A., & Schwan, S. (2011). Learning with videos vs. learning with print: The role of interactive features. *Learning and Instruction, 21*(6), 687–704. https://doi.org/10.1016/j.learninstruc.2011.03.004
Moreno, R. (2007). Optimising learning from animations by minimising cognitive load: Cognitive and affective consequences of signalling and segmentation methods. *Applied Cognitive Psychology*, *21*(6), 765–781. https://doi.org/10.1002/acp.1348
*Moreno, R., & Mayer, R. E. (2000). A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. *Journal of Educational Psychology*, *92*(1), 117–125. https://doi.org/10.1037/0022-0663.92.1.117
*Moreno, R., & Ortegano-Layne, L. (2008). Do classroom exemplars promote the application of principles in teacher education? A comparison of videos, animations, and narratives. *Educational Technology Research and Development*, *56*(4), 449–465. https://doi.org/10.1007/s11423-006-9027-0
*Muller, D. A., Bewes, J., Sharma, M. D., & Reimann, P. (2008). Saying the wrong thing: Improving learning with multimedia by including misconceptions. *Journal of Computer Assisted Learning, 24*(2), 144–155. https://doi.org/10.1111/j.1365-2729.2007.00248.x
*Muller, D. A., Sharma, M. D., & Reimann, P. (2008). Raising cognitive load with linear multimedia to promote conceptual change. *Science Education, 92*(2), 278–296. https://doi.org/10.1002/sce.20244
*Murray, D., Koziniec, T., & McGill, T. (2015). Student perceptions of flipped learning. In D. Souza & K. Falconer (Eds.), *Proceedings of the 17th Australasian Computing Education Conference* (pp. 57–62). CRPIT. https://crpit.scem.westernsydney.edu.au/confpapers/CRPITV160Murray.pdf
Newman, E. J., & Schwarz, N. (2018). Good sound, good research: How audio quality influences perceptions of the research and researcher. *Science Communication*, *40*(2), 246–257. https://doi.org/10.1177/1075547018759345
*Ouwehand, K., van Gog, T., & Paas, F. (2015). Designing effective video-based modeling examples using gaze and gesture cues. *Educational Technology & Society, 18*(4), 78–88. https://www.jstor.org/stable/jeductechsoci.18.4.78

*Ozdemir, D., & Doolittle, P. (2015). Revisiting the seductive details effect in multimedia learning: context-dependency of seductive details. *Journal of Educational Multimedia and Hypermedia, 24*(2), 101–119. https://www.learntechlib.org/primary/p/43725/

*Ozdemir, M., Izmirli, S., & Sahin-Izmirli, O. (2016). The effects of captioning videos on academic achievement and motivation: reconsideration of redundancy principle in instructional videos. *Journal of Educational Technology & Society*, *19*(4). https://www.jstor.org/stable/jeductechsoci.19.4.1

Paas, F., & Sweller, J. (2014). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 27–42). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.004

Paivio, A. (1971). Imagery and language. *Imagery: Current Cognitive Approaches*, *1971*, 7–32. https://doi.org/10.1016/B978-0-12-635450-8.50008-X

*Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthropomorphisms. *Computers & Education*, *86*, 30–42. https://doi.org/10.1016/j.compedu.2015.02.016

Persson, J. R., Wattengård, E., & Lilledahl, M. B. (2019). The effect of captions and written text on viewing behavior in educational videos. *International Journal on Math, Science and Technology Education*, *7*(1), 124–147. https://doi.org/10.31129/LUMAT.7.1.328

*Pi, Z., & Hong, J. (2016). Learning process and learning outcomes of video podcasts including the instructor and PPT slides: A Chinese case. *Innovations in Education and Teaching International, 53*(2), 135–144. https://doi.org/10.1080/14703297.2015.1060133

*Pi, Z., Hong, J., & Yang, J. (2017). Does instructor's image size in video lectures affect learning outcomes? *Journal of Computer Assisted Learning*, *33*, 347–354. https://doi.org/10.1111/jcal.12183

*Plass, J. L., Heidig, S., Hayward, E. O., Homer, B. D., & Um, E. (2014). Emotional design in multimedia learning: Effects of shape and color on affect and learning. *Learning and Instruction*, *29*, 128–140. https://doi.org/10.1016/j.learninstruc.2013.02.006

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction*, *12*(1), 61–86. https://doi.org/10.1016/S0959-4752(01)00016-0

Poquet, O., Lim, L., Mirriahi, N., & Dawson, S. (2018). Video and learning: a systematic review (2007-2017). In *Proceedings of the 8th International Conference on Learning Analytics and Knowledge* (pp. 151–160). Association for Computing Machinery. https://doi.org/10.1145/3170358.3170376

*Rey, G. D., & Steib, N. (2013). The personalization effect in multimedia learning: The influence of dialect. *Computers in Human Behavior*, *29*(5), 2022–2028. https://doi.org/10.1016/j.chb.2013.04.003

*Roscoe, R. D., Jacovina, M. E., Harry, D., Russell, D. G., & McNamara, D. S. (2015). Partial verbal redundancy in multimedia presentations for writing strategy instruction. *Applied Cognitive Psychology*, *29*(5), 669–679. https://doi.org/10.1002/acp.3149

*Saecker, L. B., Skinner, A. L., Skinner, C. H., Rowland, E., & Kirk, E. (2010). Descriptions of personal experiences: Effects on students' learning and behavioral intentions toward peers with Attention-Deficit/Hyperactivity Disorder. *Psychology in the Schools*, *47*(9), 960–973. https://doi.org/10.1002/pits.20517

*Scheiter, K., Gerjets, P., Huk, T., Imhof, B., & Kammerer, Y. (2008). The effects of realism in learning with dynamic visualizations. *Learning and Instruction*, *19*(6), 481–494. https://doi.org/10.1016/j.learninstruc.2008.08.001

*Schittek-Janda, M., Tani Botticelli, A., Mattheos, N., Nebel, D., Wagner, A., Nattestad, A., & Attström, R. (2005). Computer-mediated instructional video: A randomised controlled trial comparing a sequential and a segmented instructional video in surgical hand wash. *European Journal of Dental Education*, *9*(2), 53–58. https://doi.org/10.1111/j.1600-0579.2004.00366.x

*Schmidt-Weigand, F., Kohnert, A., & Glowalla, U. (2010). Explaining the modality and contiguity effects: New insights from investigating students' viewing behaviour. *Applied Cognitive Psychology*, *24*(2), 226–237. https://doi.org/10.1002/acp.1554

*Schmitz, F. M., Schnabel, K. P., Bauer, D., Bachmann, C., Woermann, U., & Guttormsen, S. (2018). The learning effects of different presentations of worked examples on medical students’ breaking-bad-news skills: A randomized and blinded field trial. *Patient Education and Counseling*, *101*(8), 1439–1451. https://doi.org/10.1016/j.pec.2018.02.013

*Schroeder, N., Gladding, G., Gutmann, B., & Stelzer, T. (2015). Narrated animated solution videos in a mastery setting. *Physical Review Physics Education Research*, *11*(1), 1–9. https://doi.org/10.1103/PhysRevSTPER.11.010103

*Schroeder, N. L. (2017). The influence of a pedagogical agent on learners' cognitive load. *Journal of Educational Technology & Society*, *20*(4), 138–147. https://drive.google.com/open?id=184YbdNIj2pc_rQAVM35og23mB82duYqq
*Schroeder, N. L., Chin, J., & Craig, S. D. (2020). Learner control aids learning from instructional videos with a virtual human. *Technology, Knowledge and Learning, 25,* 733–751. https://doi.org/10.1007/s10758-019-09417-6
*Schroeder, N. L., & Traxler, A. L. (2017). Humanizing instructional videos in physics: When less is more. *Journal of Science Education and Technology, 26*(3), 269–278. https://doi.org/10.1007/s10956-016-9677-6
Schüler, A., Scheiter, K., & Gerjets, P. (2013). Is spoken text always better? Investigating the modality and redundancy effect with longer text presentation. *Computers in Human Behavior*, *29*(4), 1590–1601. https://doi.org/10.1016/j.chb.2013.01.047
*Senchina, D. S. (2011). Video laboratories for the teaching and learning of professional ethics in exercise physiology curricula. *Advances in Physiology Education*, *35*(3), 264–269. https://doi.org/10.1152/advan.00122.2010
*Sharma, K., Alavi, H. S., Jermann, P., & Dillenbourg, P. (2016). A gaze-based learning analytics model: In-video visual feedback to improve learner's attention in MOOCs. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (pp. 417–421). Association for Computing Machinery. https://doi.org/10.1145/2883851.2883902
*She, H.-C., & Chen, Y.-Z. (2009). The impact of multimedia effect on science learning: Evidence from eye movements. *Computers & Education*, *53*(4), 1297–1307. https://doi.org/10.1016/j.compedu.2009.06.012
*Shen, B., McCaughtry, N., Martin, J., & Dillion, S. (2006). Does "Sneaky Fox" facilitate learning? Examining the effects of seductive details in physical education. *Research Quarterly for Exercise and Sport*, *77*(4), 498–506. https://doi.org/10.5641/027013606X13080770015409
*Shyu, H.-Y., & Brown, S. W. (1992). Learner control versus program control in interactive videodisc instruction: What are the effects in procedural learning. *International Journal of Instructional Media*, *19*(2), 85–96. https://www.learntechlib.org/p/146192/
*Spanjers, I. A., van Gog, T., Wouters, P., & van Merriënboer, J. J. (2012). Explaining the segmentation effect in learning from animations: The role of pausing and temporal cueing. *Computers & Education*, *59*(2), 274–280. https://doi.org/10.1016/j.compedu.2011.12.024
*Stull, A. T., Fiorella, L., Gainer, M. J., & Mayer, R. E. (2018). Using transparent whiteboards to boost learning from online STEM lectures. *Computers & Education*, *120*, 146–159. https://doi.org/10.1016/j.compedu.2018.02.005
Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 1–32. https://doi.org/10.1007/s10648-019-09465-5
*Szpunar, K. K., Jing, H. G., & Schacter, D. L. (2014). Overcoming overconfidence in learning from video-recorded lectures: Implications of interpolated testing for online education. *Journal of Applied Research in Memory and Cognition*, *3*(3), 161–164. https://doi.org/10.1016/j.jarmac.2014.02.001
*Tabbers, H. K., & de Koeijer, B. (2010). Learner control in animated multimedia instructions. *Instructional Science*, *38*(5), 441–453. https://doi.org/10.1007/s11251-009-9119-4
*Tan, E., & Pearce, N. (2011). Open education videos in the classroom: exploring the opportunities and barriers to the use of YouTube in teaching introductory sociology. *Research in Learning Technology*, *19*(1), 125–133. https://doi.org/10.3402/rlt.v19s1/7783
ten Hove, P., & van der Meij, H. (2015). Like it or not: What characterizes YouTube's more popular instructional videos? *Technical Communication*, *62*(1), 48–62.
*Um, E., Plass, J. L., Hayward, E. O., & Homer, B. D. (2011). Emotional design in multimedia learning. *Journal of Educational Psychology*, *104*(2), 485. https://doi.org/10.1037/a0026609
*Umutlu, D., & Akpinar, Y. (2020). Effects of different video modalities on writing achievement in flipped English classes. *Contemporary Educational Technology*, *12*(2), 1–16. https://doi.org/10.30935/cedtech/7993
*Uzun, A. M., & Yıldırım, Z. (2018). Exploring the effect of using different levels of emotional design features in multimedia science learning. *Computers & Education*, *119*, 112–128. https://doi.org/10.1016/j.compedu.2018.01.002
*van der Meij, H. (2017). Reviews in instructional video. *Computers & Education*, *114*, 164–174. https://doi.org/10.1016/j.compedu.2017.07.002

*van der Zee, T., Admiraal, W., Paas, F., Saab, N., & Giesbers, B. (2017). Effects of subtitles, complexity, and language proficiency on learning from online education videos. *Journal of Media Psychology*, *29*, 18–30. https://doi.org/10.1027/1864-1105/a000208
*Vural, O. F. (2013). The impact of a question-embedded video-based learning tool on e-learning. *Educational Sciences: Theory and Practice*, *13*(2), 1315–1323. https://www.learntechlib.org/p/154389/
Winslett, G. (2014). What counts as educational video? Working toward best practice alignment between video production approaches and outcomes. *Australasian Journal of Educational Technology*, *30*(5), 487–502. https://doi.org/10.14742/ajet.458
Wang, T. L., & Tseng, Y. K. (2019). The effects of visualization format and spatial ability on learning star motions. *Journal of Computer Assisted Learning*, *36*, 61–69. https://doi.org/10.1111/jcal.12390
*Wong, A., Leahy, W., Marcus, N., & Sweller, J. (2012). Cognitive load theory, the transient information effect and e-learning. *Learning and Instruction*, *22*(6), 449–457. https://doi.org/10.1016/j.learninstruc.2012.05.004
Wong, M., Castro-Alonso, J. C., Ayres, P., & Paas, F. (2018). Investigating gender and spatial measurements in instructional animation research. *Computers in Human Behavior*, *89*, 446–456. https://doi.org/10.1016/j.chb.2018.02.017
*Yeh, Y.-F., Chen, M.-C., Hung, P.-H., & Hwang, G.-J. (2010). Optimal self-explanation prompt design in dynamic multi-representational learning environments. *Computers & Education*, *54*(4), 1089–1100. https://doi.org/10.1016/j.compedu.2009.10.013
Yue, C. L., Kim, J., Ogawa, R., Stark, E., & Kim, S. (2013). Applying the cognitive theory of multimedia learning: an analysis of medical animations. *Medical Education*, *47*(4), 375–387. https://doi.org/10.1111/medu.12090
*Yue, C. L., & Bjork, E. L. (2017). Using selective redundancy to eliminate the seductive details effect. *Applied Cognitive Psychology*, *31*(5), 565–571. https://doi.org/10.1002/acp.3348
*Yue, C. L., Bjork, E. L., & Bjork, R. A. (2013). Reducing verbal redundancy in multimedia learning: An undesired desirable difficulty? *Journal of Educational Psychology*, *105*(2), 266–277. https://doi.org/10.1037/a0031971
*Yung, H. I., & Paas, F. (2015). Effects of cueing by a pedagogical agent in an instructional animation: a cognitive load approach. *Educational Technology & Society*, *18*(3), 153–160. https://www.jstor.org/stable/jeductechsoci.18.3.153

Corresponding author: Michael Henderson, michael.henderson@monash.edu

Please cite as: Fyfield, M., Henderson, M., & Phillips, M. (2022). Improving instructional video design: A systematic review. *Australasian Journal of Educational Technology*, *38*(3), 155-183. https://doi.org/10.14742/ajet.7296

Appendix A: Search terms

The following search terms were used with ProQuest, ERIC, and PsycInfo databases.

("Cognitive Load Theory" AND Video) OR ("Cognitive Theory of Multimedia Learning" AND Video) OR ("audio quality" AND (video* OR animation)) OR ("Coherence effect" AND (video* OR animation)) OR ("Background Music" AND (video* OR animation)) OR ("Seductive Details" AND (video* OR animation)) OR (split attention AND (video* OR animation)) OR (("attention guiding" OR signalling OR cuing) AND (video* OR animation) AND education) OR (redundancy AND (video* OR animation) AND education) OR ("worked example*" AND (video* OR animation)) OR ((realism OR first-person) AND (video* OR animation) AND education) OR (modality AND (video* OR animation) AND education NOT game*) OR (((transient OR transience) AND information) AND (video* OR animation) NOT game*) OR ("video length" OR "video duration" AND education*) OR ((("personali*ation effect") OR (personali*ation principle)) AND (video* OR animation)) OR ("pedagogical agent" AND (video* OR animation)) OR (("image principle" OR "lecturer* face" OR "presenter* face" OR "image size") AND (video* OR animation)) OR ("self explanation" AND (video* OR animation)) OR (pre-training AND (video* OR animation)) OR ("learner control" AND (video* OR animation)) OR ((segmented OR segmenting) AND (video* OR animation)) OR ("interactive video" AND activities NOT game*)

Appendix B: Coding of research papers

Variable	Description	Scoring criteria
Method	Methodology used to collect data	EX: Experiment QE: Quasi experiment CS: Case study MM: Mixed method
Video type	Style of video used	AD: Animated declarative AHT: Animated how-to AR: Animated recreation of real events DOC: Documentary style DRA: Dramatisation ID: Interview or dialogue LC: Lecture capture LB: Lightboard LHT: Live action how-to LCR: Live capture of real event NT: Narrated tablet (Khan style) PIP: Picture in picture TH: Talking head VS: Voice-over slides WE: Worked examples COM: Combination V: Various U: Unsatisfactorily described
Duration	Duration of video in seconds	Include in seconds if reported exactly Include with * if reported approximately Include multiple if up to three videos used e.g., 32, 210, 250 V: Variety (if over three videos used) NS: Not specified
Topic	Main instructional topic of the video/s	Included as reported
Domain	Main instructional domain of video/s	STEM: Science, technology, engineering, mathematics PM: Practical or manual ART: Artistic HUM: Humanities DRV: Driving

Variable	**Description**	**Scoring criteria**
		TT: Teacher training COM: Communications SPO: Sport M: Multiple
Learner control (LC)	Degree to which learners had control over the playback of the video. Multiple reported when learner control is the principle of research	S: System or instructor paced FS: Full scrubbing control PP: Pause play control LCI: Learner-controlled instructional order CC: Continue control MV: Multiple view control NS: Not specified
Display	Screen type used to show the video to learners	IND: Individual screen PRO: Projector or communal screen SO: Student own device, uncontrolled SGS: Small group screen NS: Not specified or unclear
Population (*n*)	Number of participants in total	Number reported or NA if no participants (e.g., existing data analysis)
Age or context	The learning context or level in which research took place	PRIM: Primary SEC: Secondary TER: Tertiary (conventional) MOOC: MOOC style tertiary AD: Adult PRO: Professional UN: Undefined or broad
Principles	Principles for which findings were reported	See Table 2, Column 1, for number and description of each principle
Recall (R)	Recall performance of learners reported	If recall findings reported include *, if not, leave blank
Transfer (T)	Transfer performance of learners reported	If transfer findings reported include *, if not, leave blank
Proficiency (P)	Proficiency performance of learners reported	If proficiency findings reported include *, if not, leave blank
Effect size (E)	Effect size reported	If effect size(s) reported, include *, if not, leave blank

Appendix C: Overview of included literature

Authors & year	Method	Video type	Duration (sec)	Topic	Domain	LC	Display	*n*	Age or context	Principles	R	T	P	E
Adegoke (2010)	QE	U	NS	Physics	STEM	S	PRO	517	SEC	3	*	*		*
Afify (2020)	QE	U	360*, 450*, 1500*	Digital photography	STEM	FS	SO	63	TER	9	*			*
Ali (2010)	QE	AD	20*	Cellular signal transmission	STEM	S	PRO	124	TER	6	*			
Ali (2013)	QE	AD	27*	Cellular signal transmission	STEM	S	PRO	124	TER	6	*			*
Arnone & Grabowski (1992)	EX	AD	NS	Ceramics, sculpture, painting	ART	LCI	PRO	101	PRIM	19	*			*
Austin (2009)	EX	AD	NS	Lightning	STEM	NS	IND	404	TER	3, 4, 14		*		
Barnes (2016)	QE	AD	45	Dust storms	STEM	PP	IND	135	TER	32	*			
Biard et al. (2018)	EX	LHT	312	Hand orthoses	STEM	S, PP	IND	68	TER	6, 19	*		*	
Bobrow et al. (2011)	EX	LHT	60, 300	Emergency CPR	PM	S	PRO	336	AD	9			*	
Boucheix & Forestier (2017)	EX	AHT, LHT	23, 29, 32	Nautical knots	PM	MV	IND	206	PRIM	17			*	*
Boucheix & Guignard (2005)	EX	AD	100, 250	Gearing systems	STEM	S, CC	IND	123	PRIM	2, 17, 19	*	*		
Castro-Alonso et al. (2015)	EX	LHT	92	Lego task	PM	S	IND	172	TER	23			*	
Chang (2017)	EX	WE	NS	Buoyancy	STEM	PP	IND	62, 66	SEC	6, 24, 31		*		
C.-M. Chen & Wu (2015)	EX	LC, PIP	900*	Document writing	HUM	NS	IND	37	TER	4, 21, 23, 11	*	*		
C.-Y. Chen (2016)	EX	WE	437	Adobe Illustrator	ART	FS, MV	IND	120	TER	14, 17, 19	*	*		
Cheon, Chung et al. (2014)	EX	AD	160	Lightning	STEM	S	IND	99	TER	30	*	*		*
Cheon, Crooks et al. (2014)	EX	AD	160	Lightning	STEM	CC	IND	96	TER	6, 14, 30	*	*		
Chien & Chang (2012)	EX	AD	NS	Using an Abney level	PM	FS	IND	27	SEC	31			*	*

Authors & year	Method	Video type	Duration (sec)	Topic	Domain	LC	Display	*n*	Age or context	Principles	R	T	P	E
Chung et al. (2015)	EX	AD	40	Lightning	STEM	S	SO	206	TER	14	*			*
Cook et al. (2016)	EX	WE	NS	Mathematics	STEM	NS	IND	65	PRIM	23		*	*	
Cooper & Higgins (2015)	QE	U	V (55-118)	Joint rehabilitation	STEM	FS	SO	98	TER	9			*	*
Debuse et al. (2009)	EX	PIP	1800*	Scholarly referencing	HUM	FS	SO	48	TER	3	*			
De Boer et al. (2011)	EX	U	V (53-210)	Photography equipment	STEM	FS	IND	50	TER	19	*			
de Koning et al. (2007)	EX	AD	60	Cardiovascular system	STEM	NS	IND	40	TER	2	*	*		*
de Koning et al. (2010)	EX	AD	132	Cardiovascular system	STEM	S	IND	40	TER	2	*	*		
de Koning et al. (2011)	EX	AD	305	Cardiovascular system	STEM	S	IND	90	SEC	2, 25	*			
de Koning et al. (2017)	EX	AHT	84	Patient transfer	PM	FS	IND	129	TER	3, 14	*		*	
Delen et al. (2014)	EX	DOC	960*	Renewable energy	STEM	FS	IND	80	TER	25, 31	*			*
Dousay (2016)	QE	AD	NS	Driver safety	DRV	FS	SO	102	PRO	14	*			
Dunsworth & Atkinson (2007)	EX	AD	V (203-345)	Cardiovascular system	STEM	CC	IND	51	TER	14, 23	*	*		*
Fanguy et al. (2019)	QE	PIP	NS	Scientific writing	STEM	FS	SO	110	TER	4	*			
Fiorella & Mayer (2016)	EX	LC, NT, VS	100*	Doppler effect	STEM	S	IND	157	TER	23, 2	*	*		*
Fiorella et al. (2017)	EX	LHT	82, 90	Electronic circuits	STEM	CC	IND	226	TER	10			*	*
Fountoukidou et al. (2019)	EX	AHT	NS	Eye-controlled web search	STEM	NS	NS	197	AD	23				*
García-Rodicio (2014)	EX	AD	400	Plate tectonics	STEM	CC	IND	97	TER	20, 25, 30, 31	*	*		*
Garland & Sanchez (2013)	EX	LHT	30*	Knots	PM	FS	IND	86	TER	32			*	
Guo et al. (2014)[a]	MM	V	V	Programming, Chemistry, Statistics, AI	STEM	FS	SO	NA	MOOC	1, 6, 9, 11, 16, 19, 21				
Haagsman et al. (2020)	QE	VS	1210, 1177	Molecular biology	STEM	FS	SO	170	TER	30	*			

Authors & year	Method	Video type	Duration (sec)	Topic	Domain	LC	Display	*n*	Age or context	Principles	R	T	P	E
Hasler et al. (2007)	EX	AD	225	Earth rotation	STEM	S, CC, PP	IND	72	PRIM	19	*			*
Hatsidimitris & Kalyuga (2013)	EX	AHT	90	Writing Chinese characters	ART	FS	IND	68	TER	19	*		*	*
Höffler & Schwartz (2011)	EX	AD	73	Surfactants	STEM	S/FS	IND	82	SEC	19	*	*		
Ibrahim et al. (2012)	QE	DOC	1920	Insects	STEM	S	PRO	226	TER	1, 2, 6	*	*		*
Ibrahim et al. (2014)	QE	U	NS	TPACK	TT	FS	SO	156	TER	2, 6	*	*		*
Izmirli & Kurt (2016)	QE	U	1314	Computer science	STEM	MV, LCI	IND	97	TER	14, 19	*			
Jadin et al. (2009)	EX	PIP	1500*	Industrial economic history	HUM	FS	IND	28	TER	3	*			
Jung et al. (2016)	QE	LHT	NS	Car tire replacement	PM	PP	SO	92	TER	3, 13	*			
Kay & Edwards (2012)	QE	NT, WE	141, 314, 449	Mathematics	STEM	FS	IND	136	SEC	18	*			*
Kim et al. (2014)[a]	MM	V	V	Programming, AI, Chemistry, Statistics	STEM	FS	SO	NA	MOOC	9				
Kizilcec et al. (2015)	QE	PIP, VS	V (320-1200)	Sociology	HUM	FS	SO	12468	MOOC	11	*	*		
Kopiez et al. (2013)	EX	DOC	270	Toxins in lamps	STEM	NS	SO	441	AD	7	*			
Kühl et al. (2014)	EX	AD	122*	Lightning	STEM	S, FS	IND	79	TER	8, 19	*	*		
Kulgemeyer (2018)	QE	LC	271, 286	Cars aquaplaning	STEM	S	NS	176	SEC	1, 20	*	*		*
Laws et al. (2015)	QE	COM	360*	Newton's laws	STEM	FS	SO	565	TER	31	*	*		
Leahy & Sweller (2016)	EX	VS	663	Contour maps	HUM	S	NS	71	SEC	14, 17		*		
S. Lee & Lang (2015)	EX	DOC	3600	News program	M	S	IND	288	TER	3	*			
L. Lin et al. (2016)	QE	AD	NS	Cardiovascular system	STEM	MV	IND	126	TER	2	*			*
Y.-C. Lin et al. (2015)	EX	AD	NS	Heat transfer	STEM	FS	IND	192	PRIM	3, 14, 25, 19	*	*		
Liu et al. (2020)	QE	VS, NT	485, 613	Pathophysiology	STEM	CC	NS	22	TER	23	*			*
Lynch et al. (2012)	QE	LHT	V (<120)	Paramedic skills	STEM	FS	SO	87	TER	9, 23				*
Marcus et al. (2013)	EX	LHT	69, 97	Knot tying	PM	S	IND	36	TER	23	*		*	

Authors & year	Method	Video type	Duration (sec)	Topic	Domain	LC	Display	*n*	Age or context	Principles	R	T	P	E
Mautone & Mayer (2001)	EX	AD	230	Aeroplane lift	STEM	S	IND	86	TER	2	*	*		*
Mayer & Chandler (2001)	EX	AD	140	Lightning	STEM	CC	IND	29	TER	19	*	*		
Mayer et al. (2004)	EX	AD	60*	Respiratory system	STEM	S	IND	121	TER	21	*	*		*
Mayer et al. (2008)	EX	AD	360	Immunology	STEM	S	IND	89	TER	1	*	*		*
Mayer et al. (2001)	EX	AD	140	Lightning	STEM	S	IND	78	TER	1, 3	*	*		
Mayer et al. (2002)	EX	AD	45	Braking system	STEM	S	IND	67	TER	13	*	*		
Merkt et al. (2018)	EX	DOC	773	Accoustic oscillations	STEM	S	NS	71	AD	6	*	*		*
Merkt et al. (2011)	MM	DOC	984	Post-war German society	HUM	FS	IND	212	SEC	19	*	*		
Moreno (2007)	EX	DRA, LC	1200*	Pedagogy	TT	S, CC	IND	75	TER	2, 6, 17	*	*		*
Moreno & Mayer (2000)	EX	AD	180	Lightning	STEM	S	IND	294	TER	7, 12	*	*		*
Moreno & Ortegano-Layne (2008)	EX	AR, LCR	900	Pedagogy	TT	NS	IND	80	TER	32		*		
Muller, Bewes et al. (2008)	QE	COM, ID	V (420-690)	Newton's laws	STEM	FS	SO	678	TER	27, 29	*	*		*
Muller, Sharma et al. (2008)	QE	COM	420*	Newton's laws	STEM	NS	SO	137	TER	27, 29	*	*		*
Murray et al. (2015)[b]	CS	NT, PIP, EW	V	IT server environments	STEM	FS	SO	85	TER	9, 11, 19				
Ouwehand et al. (2015)	EX	PIP	120	Mathematical problem-solving	STEM	S	IND	35	TER	11			*	*
D. Ozdemir & Doolittle (2015)	EX	AD	210	Adobe Flash	STEM	NS	IND	184	TER	1, 3	*	*		
M. Ozdemir et al. (2016)	EX	EW	NS	Lightning	STEM	FS	SO	109	TER	3			*	*
Park et al. (2015)	EX	AD	300	Immunisation	STEM	S	IND	101	TER	28	*	*		*
Pi & Hong (2016)	EX	LC, PIP, TH, VS	1500	Attachment	STEM	S	IND	96	TER	9, 11	*	*		
Pi et al. (2017)	EX	PIP	420*	Photoshop	STEM	NS	NS	87	TER	11	*			

Authors & year	Method	Video type	Duration (sec)	Topic	Domain	LC	Display	*n*	Age or context	Principles	R	T	P	E
Plass et al. (2014)	EX	AD	420	Immunisation	STEM	FS	IND	121	TER	28	*	*		*
Rey & Steib (2013)	EX	AD	V (358-380)	IT networks	STEM	NS	IND	212	SEC	2, 21	*	*		*
Roscoe et al. (2015)	QE	PIP	300*	Writing cohesion	HUM	FS	SO	90	SEC	3	*			
Saecker et al. (2010)	EX	LC	344, 453	ADHD	STEM	S	PRO	62	SEC	1	*			
Scheiter et al. (2008)	EX	AD, LCR	302	Mitosis	STEM	S	IND	120	TER	32	*			*
Schittek-Janda et al. (2005)	EX	LHT	371	Surgical hand wash	STEM	FS	IND	28	TER	6	*		*	
Schmidt-Weigand et al. (2010)	EX	AD	206	Lightning	STEM	S	IND	40	TER	14	*	*		*
Schmitz et al. (2018)	QE	ID	900*	Medical bedside manner	COM	NS	SO	114	TER	2			*	
N. Schroeder et al. (2015)	EX	WE	V (180-240)	Superposition	STEM	FS	IND	88	TER	18	*	*		
N. L. Schroeder (2017)	EX	VS	NS	Multimedia learning theory	TT	S	IND	75	TER	21	*			
N. L. Schroeder & Traxler (2017)	QE	NT	510	Frictional planes	STEM	FS	IND	99	TER	23	*	*		*
N. L. Schroeder et al. (2020)	EX	AD	123	Lightning	STEM	S, FS, CC	IND	103	TER	19	*	*		
Senchina (2011)	CS	LCR	2100	Human research interactions	COM	S	NS	72	TER	30	*			
Sharma et al. (2016)	EX	NT	511*	Resting membrane potential	STEM	NS	IND	27	MOOC	2	*			
She & Chen (2009)	EX	AD	NS	Mitosis	STEM	FS	IND	24	SEC	14	*			*
Shen et al. (2006)	QE	LHT	360	Net Games	SPO	S	PRO	240	SEC	1	*	*		*
Shyu & Brown (1992)	EX	LHT	1500*	Origami	PM	FS, MV	IND	52	TER	19			*	
Spanjers et al. (2012)	EX	AD	120*	Probability	STEM	S	IND	161	SEC	6		*		*
Stull et al. (2018)	EX	LC, LB	1200	Organic chemistry	STEM	S	PRO	55	TER	23	*	*		*
Szpunar & Schacter (2014)	EX	LC	1260	Statistics	STEM	S	IND	54	SEC	30	*			

Authors & year	Method	Video type	Duration (sec)	Topic	Domain	LC	Display	*n*	Age or context	Principles	R	T	P	E
Tabbers & de Koeijer (2010)	EX	AD	210	Lightning	STEM	LCI	IND	52	TER	19	*	*		*
Tan & Pearce (2011)[b]	CS	V	V	Sociology	HUM	S, FS	SO/PRO	75	TER	8, 7, 9				
Um et al. (2011)	EX	AD	NS	Immunisation	STEM	NS	IND	118	TER	28	*	*		*
Umutlu & Akpinar (2020)	QE	AD	1200*	Essay writing	HUM	S, FS	SO	127	TER	6, 14, 19	*		*	*
Uzun & Yildirim (2018)	QE	AD	NS	Energy conservation	STEM	FS	IND	106	SEC	28	*	*		
van der Meij (2017)	EX	WE	V (43-106)	Microsoft Word	STEM	FS	IND	77	PRIM, SEC	20			*	
van der Zee et al. (2017)	EX	U	420*	Anatomy	STEM	S	SO	125	MOOC	1, 3	*			*
Vural (2013)	QE	U	V (120-300)	PowerPoint 2010	STEM	FS	SO	318	TER	30	*			*
A. Wong et al. (2012)	EX	LHT	250	Origami	PM	S	IND	66	PRIM	17			*	*
Yeh et al. (2010)	QE	AD	NS	AVL tree data	STEM	FS	IND	244	TER	19	*	*		
Yue & Bjork (2017)	EX	AD	253	Life cycle of stars	STEM	NS	SO	69	UN	1	*	*		
Yue et al. (2013)	EX	AD	254, 312	Life cycle of stars	STEM	S	IND	107	TER	15, 3	*	*		*
Yung & Paas (2015)	EX	AD	NS	Cardiovascular system	STEM	NS	IND	133	SEC	23	*			*

[a] These studies reported on the effects of video designs on student engagement retention rather than recall, transfer or proficiency; in other words, whether students continued to watch the educational video or interact with it in various ways.
[b] These studies reported on the effects of video designs on student perception of learning rather than recall, transfer or proficiency.